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Nutritional Status and Development of Mixed Plantations of Silver Birch (*Betula pendula* Roth) and Downy Birch (*Betula pubescens* Ehrh.) on Former Agricultural Soils

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The nutritional status, growth, yield, and technical quality of mixed stands of silver birch (*Betula pendula* Roth) and downy birch (*Betula pubescens* Ehrh.) plantations in Northern Karelia, eastern Finland, were studied 20 years after planting. Soil samples were taken from all 45 field-afforestation sites and foliar samples from 23 stands.

Silver birch was greater in diameter, height and mean volume than downy birch on all the soil types studied. The difference in tree size diminished with increasing proportion of organic matter in the soil. The growth of silver birch decreased and that of downy birch slightly increased with increasing soil organic matter content. The concentrations of Ca, Mn, Fe, Al, and B in the leaves of downy birch were higher than these in silver birch leaves. Both birch species exhibited a nutrient-based growth disturbance when the foliar boron concentration was very low (below 5 mg/kg). With increasing soil organic matter content, the foliar potassium concentrations decreased and those of Mn increased. The vitality and technical quality of both downy and silver birches were at their maximum on mineral soils and much poorer on peat soils. The most common external stem defects were forks. Crown deformation was especially common on peat soils. Downy birch grew equally well regardless of what tree species grew as its neighbouring trees.

Key words: *Betula pendula*, *Betula pubescens*, nutrition, growth, technical quality, mixed stand, afforestation, arable land

Introduction

Silver birch (*Betula pendula* Roth) and downy birch (*Betula pubescens* Ehrh.) differ from each other in terms of their number of chromosomes, certain morphological properties (Kujala 1946), wood anatomy (Bhat & Kärkkäinen 1980), and also partly in regard to distribution and site preferences. Downy birch grows naturally on peatlands and poorly drained soils, while silver birch grows mostly on moist and rich upland forests. The total volume of the stock of downy birch in Finland is five times higher than that of silver birch (1180 mill. m^3 /227 mill. m^3) (Kuusela & Salminen 1983, Kuusela *et al*. 1986).

The growth and yield of silver birch (Koivisto 1959, Ilvessalo & Ilvessalo 1975, Oikarinen 1983, Niemistö 1996) and downy birch (Keltikangas & Seppälä 1977, Saramäki 1977, Ferm 1990, Niemistö 1991) has been widely studied in stands composed of either of these species. Silver birch is generally higher-yielding than downy birch (e.g. Koivisto 1959, Mielikäinen 1980, 1985, Karlsson *et al* 1997). However, studies comparing these two species are rare. Raulo (1977) has suggested relying on the development of dominant height that the yield of 30-year-old or older silver birch stands is up to two times higher than that of downy birch. It is obvious that on moist, organic soils downy birch thrives better than silver birch, and that silver birch is faster-growing on fertile upland soils.

The management guidelines for the two birch species also differ from each other (Oikarinen 1983, Ferm 1990, Niemistö 1991, 1997). The recommended growing densities for downy birch are higher than those for silver birch because the aim in growing downy birch is mainly to produce pulpwood while silver birch is grown to provide raw material for the production of veneer and plywood. There are also indications that downy birch is more shade tolerant than silver birch (Kujala 1946, Thomas & Kenworthy 1980, Atkinson 1984, Ferm 1990). The self-thinning of natural downy birch stands is slower than that of silver birch (Ilvessalo & Ilvessalo 1975).

The choice of tree species is one of the most important decisions to be made in field afforestation. The classification of old agricultural fields into mineral soil and peatland types based on vegetation, as applied in Finnish forestry, is often impossible since the field vegetation retains its dominant status for a long time (Hytönen & Ekola 1993). Both the cultivation of silver birch and downy birch in Finland was boosted by the increase in field afforestation in the beginning of 1990s. Over 220,000 ha of agricultural fields in the country as a whole, and over 33,000 hectares in North Karelia alone, have been afforested since 1969 (Finnish Statistical … 2000). Downy birch has been recommended for problematic sites, these being mostly peatland fields. It is believed that some ecological characteristics of downy birch, e.g. good tolerance for soil anaerobic conditions (Huikari 1954, 1959), make it suitable for especially wet sites. Also, silver birch has been found to be susceptible to *Godronia multispora* on peatlands (Kurkela 1973). However, growing downy birch is also problematic on former peat fields, especially if the soil's nutrient status is unfavourable (Hynönen & Makkonen 1998). Both birch species on agricultural lands run a high risk of being damaged by voles, moose, hares and fungal diseases. Thus, there are difficulties often involved when choosing to grow birch.

The aim of this study was to compare the nutritional status, growth and yield, and technical quality of downy birch (*Betula pubescens*) and silver birch (*Betula pendula*) grown on afforested former agricultural land. The effects of soil characteristics and foliar nutrient concentrations on the growth and yield of these two birch species were also studied.

Material and methods

Study stands

Field afforestations were done in North Karelia in 1971 using mixture of silver birch and downy birch. Approximately 10-20% of the birch seedlings delivered from the nursery were downy birch seedlings the rest being silver birch. The seedlings had undergone the same treatments in the nursery and their height at planting varied between 20-80 cm. The planting density was 1600 seedlings/ha. The field afforestation sites varied from 0.3 – 5.0 ha in size with the mean being 1.5 ha. The study stands were selected by accessing archives and only successful plantations were included. These stands were mostly stands still not thinned at the age of 20 years. Of the forty-five stands, eight were growing on deep peat soil, four on shallow peat soils or peat mixed with mineral soil, and thirty-one on mineral soils.

Stand measurements

Stand measurements were done 20 years after planting. For the measurements, twelve sample plots were established in each stand using a systematic network of circular sample plots. Each stand had six plots with a living planted silver birch at the centre and another six plots with a planted downy birch at the centre. Some of the stands had relatively few downy birches and in these cases a silver birch was accepted as the centre of the plot. In three of the stands, sample plots did not contain any downy birches. Altogether 526 sample plots were measured.

Within a 4-metre radius of the plot's centre all trees were mapped (direction and distance). Diameter at breast height (d 1.3, mm) and height (h, dm) and as well as the length of the centre tree's living crown were measured. Each tree was classified by crown layer, technical quality of the stem and tree vitality using standard classification (Metsikkökokeiden… 1987). The volume of each measured tree was calculated using the volume equations presented by Laasasenaho (1982). Based on the data from sample plots, the results for each stand were then calculated. The volume of silver birch trees in the stands averaged 77.3 m^3/ha and that of downy birch 7.6 m^3/ha.

Soil and foliar analysis

Soil samples from the top tilling layer (0-10 cm) were taken from the centre of each plot near the sample tree (within 0.5 – 1.5 m) and these were formed from four subsamples. The means for the whole stand were calculated.

Soil samples were analyzed for their pH (H_2O), total nitrogen (Kjeldahl), and acid ammonium acetate extractable (pH 4.65) P, K, Ca, and Mg (Halonen *et al.* 1983). The mineral soil's particle size distribution was determined after drying the soil samples by sieving (sieve mesh size: 20, 2.0, 0.63, 0.2 and 0.063 mm). The organic matter content of the topsoil was highest in peat soils and lowest in mineral soils. This was not tested (Table 1) since the classification in the field was based on the assessed content of organic matter. The nutrient concentrations were highest in peat soil, except for potassium, which had the highest concentrations in soils formed of a mixture of mineral soil and peat soil (Table 1); in the latter, the nutrient concentrations were in between those of mineral and peat soil. The soil's pH was higher in the mixture than in the other soil types.

Table 1. Soil nutrient concentrations (acid ammonium acetate extractable P, K, Ca, Mg), pH and organic matter content by soil type

Nutrient	Mineral soil n= 29	Peat soil n=10	Mixture n=4	F	p
N tot. %	0.3	1.4	0.7	39.47	0.000
P, mg/l00 g	0.5	1.6	0.4	17.46	0.000
K, mg/l00 g	7.4	14.1	15.0	10.95	0.000
Ca, mg/l00 g	63.3	296.6	187.0	15.41	0.000
Mg, mg/l00 g	6.2	24.5	20.9	14.56	0.000
pH	5.2	4.8	5.3	8.19	0.001
OM, %	11.7	51.9	25.6	-	

Leaf samples were taken from both birch species in twenty-three stands (eleven on peat based fields and twelve on mineral soils) during mid-August 1990. The leaf samples were stripped from the most recent leaders, from just above the mid-point of the crown from the south side of the sample trees serving as the mid-point of each sample plot. In each study stand six separate samples for silver birch and downy birch were collected for analysis. The standwise means for silver and downy birch were subsequently calculated.

The birch leaves were analyzed for their ash content, N concentration using the Kjeldahl method, P and B concentrations were measured spectrophotometrically, and, K, Ca, Mg, Fe, Mn, Zn, Cu, Na, and Al concentrations were measured using ICP (Halonen *et al*. 1983).

Statistical analyses

The differences between the mean volume of trees, mean height and the diameter of the two species were tested with analysis of variance (model included: species, soil type and interaction) and t-test and differences between the soil types with analysis of variance. Since the number of soils classified as mixtures was only four, they were combined with peat soils and classified as organic soils. The effect of particle size distribution, the soil's nutrient concentrations and the pH on the size and volume of the trees were tested with correlation analysis.

Results

Foliar nutrient concentrations

The differences between foliar nutrient concentrations in regard to nitrogen, phosphorus, potassium, and magnesium were small (Table 2). Silver birch had 0.7 mg/g higher nitrogen concentration than downy birch, but this difference was significant. The maximum values of foliar nitrogen concentration exceeded 30 g/kg. Downy birch had significantly higher calcium, manganese, iron, aluminum, and boron concentrations than silver birch.

Table 2. Foliar nutrient concentrations of silver birch and downy birch. Means, standard deviations and minimum and maximum values. F and p statistics

Nutrient	Silver birch x	s	Min.	Max	Downy birch x	s	Min	Max	F	p
N, mg/g	27.4	1.7	23.5	31.7	26.7	1.9	22.7	29.9	8.68	0.007
P, mg/g	2.65	0.41	2.01	3.47	2.71	0.37	2.15	3.55	1.57	0.223
K, mg/g	10.22	2.67	5.91	18.35	10.37	2.34	7.10	15.88	0.21	0.650
Ca, mg/g	9.93	1.17	7.88	12.22	10.77	1.44	7.58	13.96	5.33	0.031
Mg, mg/g	2.95	0.49	2.16	4.19	2.82	0.45	2.15	4.11	3.19	0.088
Mn, mg/kg	1001	654	195	3072	1214	715	169	3407	16.98	0.000
Fe, mg/kg	77	16	54	121	90	13	69	128	32.19	0.000
Al, mg/kg	71	13	48	95	82	13	66	117	34.76	0.000
Cu, mg/kg	6.1	0.7	4.3	7.1	6.3	0.7	4.7	7.4	0.93	0.339
Zn, mg/kg	176	79	69	335	187	87	88	366	2.73	0.113
B, mg/kg	12.9	8.1	3.6	37.2	17.2	10.3	4.2	49.6	25.74	0.000

In 22% and 48% of the stands downy and silver birch foliar boron concentrations were below 10 mg/kg deficiency limit set by Ferm and Markkola (1985). Of the twenty-three stands examined, four exhibited obvious macroscopic nutrient-based growth disturbance symptoms (Raitio 1983, Ferm & Markkola 1985) with concurrent extremely low (average value 4-5 mg kg) boron concentrations in the leaves. Even in these cases, downy birch exhibited boron concentrations values slightly higher than those of silver birch. The nitrogen boron ratios in the leaves were also high (6000-8000).

The soil type had a statistically significant effect on the concentrations of some of the nutrients. The foliar phosphorus and potassium concentrations of birch decreased with increasing proportion of soil organic matter. This was statistically significant only for silver birch (Table 3, Figure 1). When the share of soil organic matter increased, the foliar N/K-ratios of both silver birch ($r=0.743$, $p = 0.000$) and downy birch ($r=0.602$, $p=0.002$) also increased with statistical significance. Also, the foliar iron concentrations of silver birch increased when the share of organic matter in the soil increased (Table 3). Both species showed marked and significant increase in their manganese concentrations with increasing soil organic matter (Figure 1). Thus, the concentrations of manganese were highest in peat-based fields. Downy birch had in 30% and silver birch in 17% of the stands manganese concentrations over 1500 mg/kg. The highest manganese concentrations exceeded 3000 mg/kg. The corresponding soil and foliar nutrient concentrations did not correlate statistically significantly with each other.

Table 3. Correlation coefficients between soil organic matter content and foliar nutrient concentrations

Species	N	P	K	Ca	Mg	Mn	Fe	Al	Cu	Zn	B
Silver birch	0.196	-0.474*	-0.522*	-0.015	0.222	0.807**	0.443*	-0.114	0.208	-0.133	0.216
Downy birch	0.227	-0.380	-0.380	-0.247	0.021	0.815**	0.063	-0.153	-0.165	-0.252	0.125

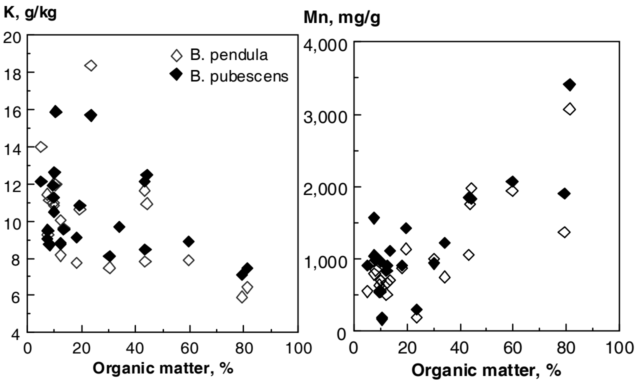

Figure 1. Correlation between soil organic matter content and foliar potassium and manganese concentrations

Table 4. Standwise mean characteristics and minimums and maximums

Characteristics		Mean	Standard deviation	Minimum	Maximum	N
Mean diameter (cm)	Silver birch	12.0	1.6	8.8	16.1	45
	Downy birch	7.4	1.7	4.5	11.5	42
Mean height (m)	Silver birch	11.6	1.5	8.2	14.5	45
	Downy birch	8.8	1.6	5.5	12.7	42
Mean volume (dm^3/tree)	Silver birch	72.9	24.7	32.9	143.4	45
	Downy birch	23.8	12.8	6.0	63.1	42
Stocking (stems/ha)	Silver birch	1124	334	82	1940	45
	Downy birch	324	235	17	1144	42

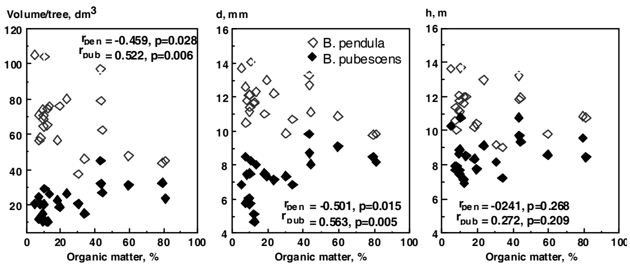

Figure 3. The correlation between soil organic matter content and volume, mean diameter and mean height of silver and downy birch (n=23 stands)

Tree and stand characteristics

Mean diameter

The mean diameter of silver birch on all soil types and in all stands was higher than that of downy birch (Figure 2, Table 4). The differences between the species were statistically significant (F=136.57, p=0.000). Soil types did not differ from each other, but there was significant interaction between soil type and tree species (F=14.58, p=0.000). The diameter of silver birch was higher on mineral than on organic soils, and that of downy birch was vice versa (Figure 3). The differences in the mean diameters between the dominant individuals of these two birch species were much smaller than the diameter of all trees. On mineral soils, the mean diameter of all planted silver birch was 5 cm larger than that of downy birch. The corresponding difference in the mean diameter of the dominant trees was only 2.6 cm. The corresponding figures for peat soils were 2.7 cm and 1.7 cm.

The mean diameters of both tree species did not correlate statistically significantly with the particle size on the mineral soils nor with the soil nutrient concentrations.

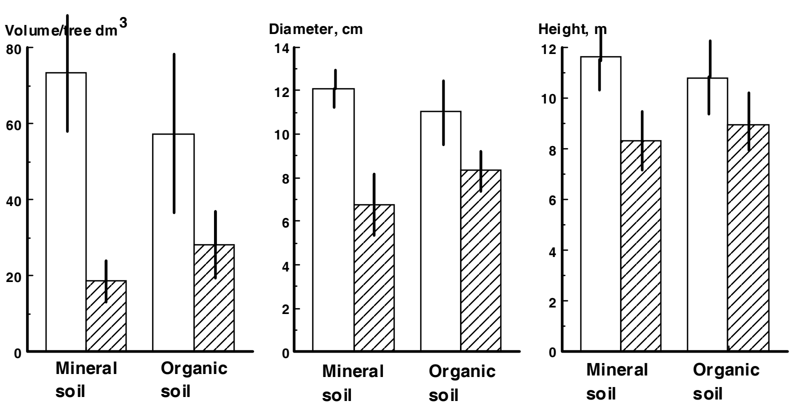

Figure 2. The mean volume, mean diameter and mean height of silver birch and downy birch growing on mineral and organic soils. Standard deviation marked inside the columns

Mean height

Independing of the soil type, silver birches were taller than downy birches (F=50.10, p=0.000) (Figures 2, 3, Table 4). The differences in heights were bigger on mineral soils than on peat soils, but the differences were not statistically significant. Also, the interaction between the soil type and tree species was not significant (F=4.01, p=0.052).

The mean heights of both silver and downy birch decreased slightly when the share of silt and clay in the soil increased. However, these correlations were not statistically significant.

The height of downy birches on average was 82% of the height of all trees in the stands and that of silver birch trees correspondingly 111%. Downy birch was in intermediate or suppressed position in almost all plantations. However, on peat soils downy birch was in a more competitive position compared with silver birch (Table 5).

Table 5. The distribution of trees (%) into crown classes by soil type

Site type	Crown class Dominants	Co-dominants	Intermediate	Suppressed
	Mineral soils			
Silver birch	50.8	25.0	16.9	7.3
Downy birch	5.5	14.5	41.4	38.4
	Peat soils			
Silver birch	57.0	24.5	15.1	3.4
Downy birch	19.6	26.0	42.9	11.4
	Mixture of peat and mineral soil			
Silver birch	42.4	27.8	21.7	8.1
Downy birch	5.1	11.9	47.5	35.6

Mean volume of tree

The mean volume of the average silver birch was higher than that of downy birch (F=107.43, p=0.000) (Figures 2, 3, Table 4). The differences between soil types were not statistically significant (F=0.52, p=0.436), but there was significant interaction between the species and soil type (F=10.18, p=0.000). The mean volume of the average downy birch was higher on peat soils than on mineral soil fields, and the mean size of silver birch was higher on mineral soil and lowest on peat soils. On all fields, silver birch was bigger than downy birch. The ratio between the mean volumes on mineral soils was 3.3 and on peat soils 2.3. In stands where top soil was mineral (organic matter content < 20%), silver birch was at least three times larger than downy birch, and in some cases over ten times larger (Figure 2). Even when the soil organic matter content was high, the average size of silver birch was 2.5-1.5 times greater than that of downy birch. No statistically significant correlation, however, was noted between the soil nutrient concentration and tree size.

Stand volume

The volume of silver birch in stands was at its maximum on mineral-soil sites and at its minimum on peat-based sites. The maximum stand volumes of downy birch were recorded on peat-based fields.

When the amount of soil organic matter increased, the total volume of birch stands decreased (r=-0.441, p=0.035). This is explained by the decreasing size of dominant silver birch trees with an increase in the organic matter content. The positive correlation with soil pH and stand total volume (r=0.429, p=0.009) was probably due to pH being at its lowest on peat-based fields. Soil potassium, as well as other measured soil parameters, did not correlate with stand volume. The foliar potassium concentrations in both birch species correlated significantly with the mean stand volume ($r_{pendula}$=0.783***, $r_{pubescens}$=0.728***) (Figure 4). This was most probably due to silver birch growing less on peat-soil sites than on mineral-soil sites.

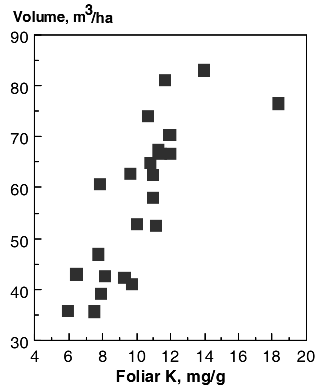

Figure 4. Correlation between silver birch's foliar concentrations of potassium and stand mean volume

Technical quality and vitality of trees

The most common external defects in both birch species were abnormalities of the stem and of the crown: crooked or forked stems and bushy appearance of the crown. The proportion of dead trees was, however, small. On mineral soils, 71% of the silver birch trees were assessed as being normal in terms of technical quality and the corresponding figure for downy birch was 65% (Table 6). On peat-based sites, the proportion of normal trees was lower, with only 46% of the trees of both species being normal in terms of technical quality. Forking was the most general technical defect lowering technical quality (Table 6). Forking in silver birch was more common than in downy birch on all soil types. Silver birch was more crooked on all site types than was downy birch.

Table 6. The technical quality of stems (%) by site type

Technical quality	Mineral soil Silver b.	Downy b	Peat soil Silver b.	Downy b.	Mixture Silver b.	Downy b.
Normal	71.4	65.2	46.0	45.5	52.4	60.6
Branchy	-	-	-	0.4	-	-
Crooked	11.2	10.1	14.2	10.3	20.3	12.8
Forked	13.3	20.8	23.3	33.3	22.0	22.9
Branchy+ crooked	-	-	0.5	-	-	-
Crooked+ forked	4.1	3.9	14.6	10.1	5.1	3.7
Branchy+ crooked+forked	-	-	1.4	0.4	-	-
	100.0	100.0	100.0	100.0	100.0	100.0

The vitality of the trees was better on mineral soil sites than on peat-based sites (Table 7). Deformation of the crown was the most general disorder. It was especially common on peat soils in both species. Other disturbances related to vitality were rare.

Table 7. The distribution (%) of tree vitality by site type

Vitality	Mineral soil Silver b.	Downy b.	Peat soil Silver b.	Downy b.	Mixture Silver b.	Downy b.
Healthy	69.6	72.1	46.6	51.6	64.4	70.3
Dead	6.4	1.7	0.9	2.6	1.7	0.5
Stem injury	1.1	1.0	0.9	1.9	-	0.2
Top broken	1.1	0.6	0.9	0.4	5.1	0.2
Abnormal crown	13.2	21.3	36.5	41.3	25.4	25.4
Defoliation	8.6	3.3	14.2	2.2	3.4	3.4
	100.0	100.0	100.0	100.0	100.0	100.0

Effect of species mixture

The numbers of downy birch were highest and the numbers of silver birch lowest on peat-based fields. On mineral-soil-based fields the numbers of both birch species were almost the same. The total numbers of trees on mineral-soil and peat-based fields were 1480 and 1417 trees/ha respectively.

Downy birch was of the same stem size both on mineral-soil-based and peat-soil-based fields, independent of the neighbouring tree's species (silver or downy birch). The stem size of downy birch did not appear to depend on the mixture of downy birch in the stand. However, the more downy birch there was in the stand, the bigger the average size of silver birch in those stands. This was observed both on mineral-soil and peat-soil fields. This could be due to downy birch being smaller than silver birch and therefore not presenting such heavy competition to silver birch as do other silver birch individuals.

Discussion

There were great differences in the growth and development of the two birch species. Silver birch grew better than downy birch in all the examined stands to the extent that on the best sites silver birch appeared to subdue the admixture of downy birch. The growth of silver birch corresponded, on average, to height index 26 (Oikarinen 1983), which is equivalent growth to be expected on the *Oxalis-Myrtillus* site type according to the Finnish site classification (Cajander 1926). As downy birch was not in a dominant position in the stands examined, their site index could not be defined. In western Finland, the growth of silver birch on afforested fields has also corresponded to height class 26 (Kinnunen and Aro 1996).

The growth of birch varied quite a lot between the stands. Silver birch grew better than downy birch on mineral-soil-based fields, where its arithmetic mean volume (73.4 dm^3/tree) was clearly higher than the arithmetic mean volume of downy birch (22.4 dm^3/tree). Silver birch grew better on mineral soils than on organic soils, and its growth decreased with increasing soil organic matter content. This is in agreement with earlier results, according to which the yield of silver birch on soils suitable for it has been better than that of downy birch. According to Raulo (1977), the yield difference at the age of 30 years can be as much as 50% in favour of silver birch. The mean volume of silver birch was also higher on peatland sites mostly considered to be suitable for downy birch. The arithmetic mean volume of silver birch on peat-based fields was 71 dm^3/tree and that of downy birch was 31 dm^3/tree. Heiskanen (1957) has also reported that the mean diameter of silver birch on peatlands is higher than that of downy birch of the same age. The size of individual downy birch trees slightly increased with increased soil organic matter content and the size difference between silver and downy birch decreased. Karlsson *et al*. (1997) found that on moist sites in central and southern Sweden the site index for downy birch was as high as the site index for silver birch.

The various defects impairing the technical quality of birch stemwood and the vitality of the trees appeared to be related to the site. The proportion of normal trees (silver birch 65%, downy birch 72%) was highest on mineral-soil fields. On peatland fields, the proportion of normal trees was less than 50%. The main defects lowering the technical quality of birch stems were forks and stem crooks as have been reported for silver birch in other studies (e.g. Kinnunen and Aro 1996, Niemistö 1996, Hynönen and Saksa 1997a, 1997b, Hytönen 1999). In this study, one-third of the silver birches growing on peat-based fields were forked.

Downy birch stems had more crooks than silver birch stems. The reason for this remains unexplained, but it could be related to moose damage, for example. According to Heiskanen (1957), old downy birch individuals are more crooked and the crooks are often worse than in silver birch of similar age. Also in the study of Verkasalo (1988), the most common single defects in veneer-log-sized downy birch stems on peatland forests were crooks.

The soil pH was relatively high (4.7-5.3), and close to the average pH of Finnish arable soils as recorded in the 1960s (Lakanen *et al*. 1969). The soil pH correlated with the stand volume of the birches. However, according to Ferm and Hytönen (1988) and Rikala and Jozefek (1990), pH does not limit the growth of birch. Thus, the positive correlation between pH and growth is probably linked to pH being lowest on peatland soils.

None of the measured soil nutrient concentrations correlated with stand growth. The nutrient amounts in the peat soil of afforested former agricultural peatlands are often quite high compared with the soils of peatland forests (Kaunisto & Paavilainen 1988, Hytönen & Ekola 1993, Wall & Hytönen 1996, Hytönen & Wall 1997, Hynönen & Makkonen 1999). Agricultural treatments have been found to increase the bulk density, ash concentration, pH, and the total amounts of phosphorus, calcium and iron in the cultivation layer of the soil, but these treatments have had only a minor effect on the amounts of potassium, magnesium, and boron (Hytönen and Wall 1997). The use of mineral soil as a soil improvement agent was common practice when these peat fields were under cultivation. Mineral soil has a long-term positive effect on the thermal conditions and fertility of peat, especially on the potassium status of soils, even though it has usually not increased soil boron amounts (Wall & Hytönen 1996, Hytönen & Wall 1997). In this study, the soil's organic matter content correlated with the foliar potassium concentrations of birch. Further, it was shown that both the soil's organic matter content and foliar potassium concentrations correlated with stand volume. Even though the soil's potassium concentrations in this study did not correlate with the growth of birch, Hynönen and Makkonen (1999) reported a statistically significant correlation between the soil's extractable potassium concentrations and the height increment of 3 to 7-year-old downy birch on peat-based fields. Also, in cutaway peatland areas potassium has been shown to be a critical nutrient for the growth of downy birch (Ferm & Kaunisto 1983). Thus, it seems that on the peat-based fields potassium can limit the growth of birches.

Scots pine growing on afforested fields has been shown to be susceptible to nutritional growth disturbances and boron deficiencies (Raitio 1979,Veijalainen 1983, Ferm *et al.* 1992, Hytönen & Ekola 1993, Hytönen 1999, 2003). Liming of fields during cultivation can also contribute to an increased risk of boron deficiency (Lehto & Mälkönen 1994). In this study, the foliar boron concentrations in birch were low (below 10 mg/kg, see Ferm and Markkola 1985) in 22% and 48% of downy and silver birch stands, respectively. Low boron and high nitrogen concentrations were associated with nutrient-based growth disturbances. Crown defects were mostly connected to nutritional disorders (see Ferm and Markkola 1985) and clearly visible when foliar boron concentrations were close to 5 mg/kg. As with nutrient-based growth disorders in Scots pine and Norway spruce, typical features in birch are frequent diebacks, leader damage and bushy crowns (Raitio 1982, Veijalainen *et al.* 1984, Ferm and Markkola 1985). Crown deformations were more common on peatland sites than on mineral-soil fields. The defects had in some stands also clearly affected the growth and yield of trees. For example, trees with severe canopy defects had almost ceased to grow in height and their volume growth was reduced.

The two birch species studied differed from one another in their calcium, manganese, iron, aluminum and boron concentrations. These concentrations were higher in downy birch than in silver birch. Both iron and manganese are far more soluble in anaerobic soils. Manganese in excessive concentrations can be toxic to the plants. Raitio (1982) found mild and severe injuries and disturbances in silver birch on growing alluvial soil with foliar manganese levels of 1650 and 3590 mg/kg. He related the disturbance symptoms to excessive moisture and manganese intoxication (Raitio 1982). In this study, such high manganese concentrations were common in both birch species. The higher manganese and iron concentrations in downy birch compared to those found in silver birch could be an indication of downy birch having better tolerance of the anaerobic conditions occurring on peatland growing sites.

High soil moisture content could be one of the significant factors affecting the growth of silver birch even on mineral soil fields. Excessive moisture of the growing site has been assessed to limit the growth of silver birch on mineral soil fields in western and eastern Finland and central and southern Sweden (Kinnunen and Aro 1996, Hynönen and Saksa 1997b, Karlsson *et al*. 1997). Hynönen and Saksa (1997a) reported that the volume of silver birch stands was fivefold when the drainage of stands growing on mineral soils was good. The soil's physical properties in the case of afforested former agricultural peat soils are generally fairly unfavourable considering the adequacy of aeration for forest growth (Wall and Heiskanen 1998). This could favor the use of downy birch in field afforestation. The roots of downy birch seedlings are able to grow better than those of silver birch in anaerobic conditions according to the results obtained in laboratory studies (Huikari 1954, 1959). Grosse *et al*. (1992) have also shown that downy birch can transport oxygen-rich gases to its root system when the oxygen content of the soils decreases.

Silver birch grew better than downy birch on all sites, but the growth of silver birch decreased and that of downy birch slightly increased with increasing soil organic matter content. On good mineral soil sites, silver birch is the recommended choice. General opinion, supported by research results (e.g. Raulo 1981, Karlsson *et al*. 1997), indicates that on moist or silty and clayey mineral soils the growth of silver birch is poorer. According to the present and several other studies, silver birch does far more poorly on peat-based fields than on mineral-soil-based fields (Valtanen 1991, Rossi *et al* 1993, Hytönen 1999). Peatlands are generally considered unsuitable for growing silver birch (Lehtiniemi & Sarasto 1973, Raulo 1981), albeit that studies reporting large numbers of naturally regenerated seedlings and good initial development of planted silver birch on fertilized or rich sites have also been published (Mannerkoski 1972, Kaunisto 1973). However, even though silver birch grew better on mineral-soil-based fields, its growth still surpassed that of downy birch also on peatland fields, even though the relative difference decreased with increasing soil organic matter content. Silver birch has regenerated and grown well on cutaway peatland sites where the substrate has been fertilized or where the stand is able to utilize the nutrient reserves, especially potassium, of the mineral soil (Kaunisto 1981, Ferm & Kaunisto 1983, Hytönen & Kaunisto 1999). Also, when single silver birch trees are found in peatlands, they are usually larger than downy birch trees (Saramäki 1973). Growing of downy birch (Heräjärvi 2002) and probably also growing of silver birch for high-quality veneer on peatland sites is questionable. According to the present results growing of silver birch besides mineral soil fields also on well-drained peatland fields could be feasible. However, since soil characteristics in peatland fields differ considerably from those of normal peatland sites these results can't be applied to peatland forests. Both birch species planted on agricultural land are susceptible to similar problems related to damage (especially by moose and voles and stem spot disease), competition from ground vegetation, and nutritional disorders (Hytönen 1998a,b, Saksa *et al*. 2003).

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СОСТОЯНИЕ ПОЧВЕННОГО ПИТАНИЯ И РАЗВИТИЕ СМЕШАННЫХ БЕРЕЗОВЫХ *BETULA PENDULA* ROTH И *BETULA PUBESCENS* EHRH МОЛОДНЯКОВ НА БЫВШИХ СЕЛЬСКОХОЗЯЙСТВЕННЫХ ПОЛЯХ

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Резюме

В Северной Карелии 20 лет тому назад были созданы смешанные насаждения, представленные берёзой бородавчатой (*Betula pentula* Roth) и берёзой пушистой (*Betula pubescens* Ehrh.). На 45- ти участках исследовалось состояние питательных веществ, рост, продуктивность и техническое качество древесины этих молодняков.

На всех участках исследования на рыхлых осадочных породах у берёзы бородавчатой диаметр, высота и средний объём ствола превышали соответственные показатели берёзы пушистой. Разница между обьёмами деревьев уменьшалась при повышении количества органических веществ в почве.

В листьях пушистой берёзы содержание Ca, Mn, Fe, Al, и B было больше, чем соответственно у бородавчатой берёзы.

У обоих видов берёзы наблюдалось угнетение роста, когда содержание бора в листьях было очень низкое (ниже 5мг/кг).

При возрастании количества органичестких веществ в почве понизилось содержание калия в листях, а содержание марганца возросло. Состояние и технические качества у берёзы пушистой и у берёзы бородавчатой были лучшие на минеральных почвах, и намного хуже (большая деформация крон) на торфяных почвах.

Ключевые слова: экономика питательных веществ, прирост, технические качества, смешанный лес, облесение сельскохозяйственных полей